(54) Title: A METHOD AND APPARATUS FOR LINK QUALITY ESTIMATION IN A MOBILE COMMUNICATION NETWORK
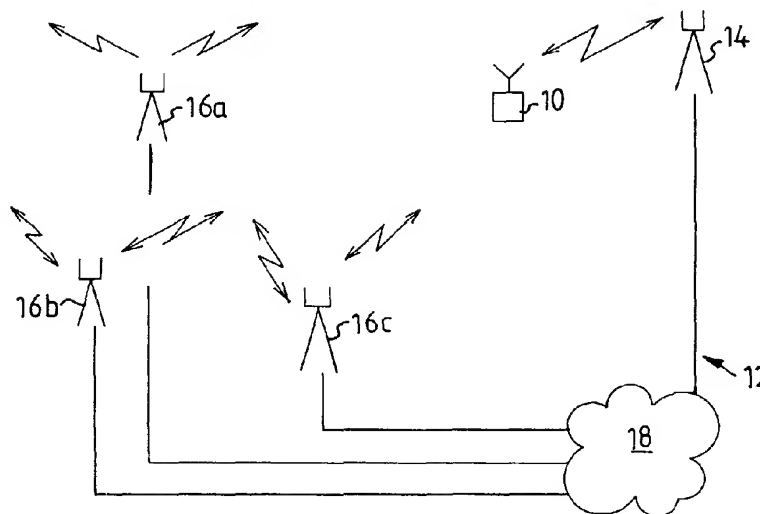
(57) Abstract: A method and apparatus for link quality estimation of a potential TDMA-based wireless communication link between a mobile station (10) and a target base station (16a-c). The mobile station (10) receives a signal on a channel frequency of the target base station (16a-c) for measuring a link quality and identifying the target base station (16a-c) simultaneously based on the same received signal. The mobile station (10) qualifies the measurement if the target base station (16a-c) was identified properly. If not, the measurement is discarded. Measurements can then be tied to specific base stations more reliably, and are at the same time up to date when reported. This provides for secure connections and enables a tighter frequency reuse for enhancing the overall traffic capacity in the network.

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

A METHOD AND APPARATUS FOR LINK QUALITY ESTIMATION IN A

MOBILE COMMUNICATION NETWORK

5   TECHNICAL FIELD

The present invention relates generally to a
method and apparatus for estimating the quality of a
communication link between a mobile station and a base
station, which may be used to select a base station for
10   connection. In particular, the invention provides more
reliable link quality measurements by the mobile station.

BACKGROUND OF THE INVENTION AND PRIOR ART

A mobile communication network typically includes
15   a plurality of base stations being connected together by
means of switching nodes such as a Base Station Controller
(BSC) and/or a Mobile Switching Centre (MSC). Each base
station provides radio coverage over an area known as a cell
for radio communication with mobile stations located
20   therein. Each mobile network is allocated a certain limited
radio frequency spectrum for transmissions, and efforts are
made by network designers to provide the greatest possible
traffic capacity within the allocated spectrum. In other
words, the number of possible ongoing call connections over
25   radio channels is maximised.

In a TDMA-based cellular network, each cell is
typically allocated a number of specified radio frequency
channels to be used for call connections and for
broadcasting information to mobile stations. Typically, the
30   closest neighbour cells cannot use the same frequencies for
connections and broadcasts since that would result in
unacceptable levels of interference between the ongoing

transmissions. Therefore, frequency channels are reused in cells at a sufficient distance as to not interfer too much with each other, in order to increase traffic capacity in the network. Cell planners are concerned with allocating

5   frequencies to the cells in a network employing a reuse pattern, which is generally well-known in the art.

Great efforts are made to be able to employ as tight reuse pattern, i.e., short reuse distances, as possible in order to maximise traffic capacity. An important

10   factor to consider is to select transmission power levels for calls and broadcasts as low as possible for reducing interference, and mechanisms have been proposed for obtaining an accurate power control for ongoing calls.

Another area of interest is the selection of the

15   most appropriate base station (BS) for connection. If a mobile station (MS), being located in one cell and connected to a serving BS, moves away from that BS towards a neighbouring BS, the received signal strength or link quality of the old BS will decrease and that of the new BS

20   will increase such that the new BS becomes more suitable for connection, requiring less transmission power. There are various known mechanisms for switching connection from the old BS to the new BS. This is often referred to as "handover" or "handoff" when the mobile station is in busy

25   mode, i.e., engaged in a call, and "cell selection" or "cell reselection" when in idle mode, i.e., not engaged in a call but powered-on. This will commonly for both modes hereafter be referred to as "BS selection".

BS selection is a fundamental process whereby each

30   MS aims to connect to an appropriate BS in order to maximise the connection link quality and minimise transmission power, and thus the interference to others. In most cellular

networks of today, MSs are responsible for making
measurements on signals from neighbouring BSs as well as
from the serving BS, and reporting the results to the
serving BS for comparison. To achieve this, each BS
5 continuously transmits a signal on at least one so-called
broadcast frequency upon which MSs in the network can make
link quality measurements with respect to, e.g., signal
strength and/or interference. By matching a certain
measurement to a certain BS, the link quality of various BS
10 candidates are compared, and an MS can then attempt to
connect to the most appropriate BS during BS selection. In
the vicinity of an MS there are typically many BS candidates
to which BS selection could occur. In some systems, it is
required that the MS qualifies the measurement by
15 identifying a target BS before reporting it to the serving
BS.

        Clearly, measurements must be made on all the
potential BS candidates in order to determine the most
appropriate one for the connection. In order to correctly
20 ascribe a certain measurement to a certain BS, each BS in
the area must be able to uniquely identify itself by means
of the broadcasted signal. When an MS initially connects to
a BS, that BS transmits a measurement order including a list
of neighbour BSs to be measured by the MS. Such a neighbour
25 list is pre-defined for each cell and includes an identity
and a broadcast frequency channel of each neighbour BS. The
BS identity is in GSM referred to as the Base Station
Identity Code (BSIC), which comprises a Network Colour Code
(NCC) and a Base station Colour Code (BCC). The number of
30 BSs included in the neighbour list is typically in the range
of 10 - 32, depending on cell configurations in the network.

The MS then performs the link quality measurements according to the received neighbour list during periods when the MS is not transmitting or receiving signals of its own connection with the serving BS. When in idle mode, the MS is
5 sleeping most of the time for saving battery and wakes up only occasionally, e.g., listening for paging messages or transmitting location updates, according to a predetermined schedule, leaving plenty of time for measurements. In busy mode, the MS normally transmits during a timeslot of an
10 uplink TDMA frame and receives during a timeslot of a downlink TDMA frame. The uplink and downlink frames are offset from each other such that there are typically one or more free timeslot periods available for measurements between the busy ones. Measurements in busy mode are often
15 referred to as MAHO (Mobile Assisted Handover) measurements.

There are some drawbacks in the measurement methods used or proposed so far, which will be outlined below. The present invention is concerned with reducing or eliminating these drawbacks.

20 In present measurement methods when measuring a particular target BS according to the neighbour list, the MS tunes to the specified channel frequency and measures the link quality thereof. The MS also tries to decode or detect the received signal on that frequency in order to read an
25 identity code for the target BS, e.g., the BSIC, by receiving at least one burst during a timeslot containing that identity code. In GSM, the BSIC is included in bursts of the logical synchronisation channel (SCH). However, the measuring and decoding are at present separated in time such
30 that they are performed on different received bursts. Several problems may then arise:

1)   The interference level may be too high at the moment
of decoding such that the MS fails to decode the received
signal, although the measurement may indicate a strong BS
candidate. At least one broadcast channel frequency is
transmitted continuously at a predetermined power level by
each BS. Mobile networks are typically configured so that
the broadcast frequencies are reused at the closest
possible distances, which typically results in
interference problems in some areas.

2)   The MS may decode the identity of another BS which
reuses the same frequency as the target BS, if the signal
from the wrong BS happens to be stronger due to the signal
propagation conditions during the decoding attempt.
Therefore, the measurement may be ascribed to the wrong
BS. Moreover, if the correct identity, e.g., BSIC, was
decoded earlier, all measurements made on that frequency
during the current measurement period are discarded, even
though they may be valid measurements on an important
handover candidate.

3)   The BS identity code may not be included in the one or
more bursts received from the target BS, since the
broadcast channel includes a plurality of logical channels
transmitted at different times according to a
predetermined schedule. The logical channels may include a
frequency correction channel (FCCH), a synchronisation
channel (SCH) and other common or dedicated control
channels as well as traffic channels for MS connections.
Not all of these logical channels include a BS identity.

       In prior solutions, the remedy for the interference
problems referred to above has been to allocate a unique
broadcast frequency to each BS in relatively large areas,

resulting in a sparse frequency reuse. However, this gives
rise to other problems since the number of available
frequencies is limited and few are then left for call
traffic. Since the capacity of pure traffic channel
5   frequencies is much larger than that of broadcast
frequencies, the sparse and inefficient reuse of broadcast
frequencies constitutes a major limiting factor for overall
system capacity.

In EP 0886453 A3, a method is described for
10   identifying a neighbor BS in order to qualify field strength
measurements made by an MS. The detection of BSIC is made
more reliable by using frame timing difference data or data
for discontinuous transmission, which data is received from
a serving BS. This data is used to ensure that the BSIC is
15   detected from the correct neighbor BS. However, no solution
is described for connecting quality measurements to a
particular neighbor BS.

If the MS fails to decode or detect an expected BS
identity, the MS is typically configured to make further
20   identification attempts, which will take some time. For
example in GSM systems, the MS is configured to make three
additional identification attempts before discarding a
particular measurement. Even if the first attempt is
successful, it could take typically 5 seconds after the
25   measurement before the result is reported to the serving BS.
For each additional identification attempt, the delay
increases by 2.4 seconds. Furthermore, a reported
measurement is typically an average value of measurements on
plural received bursts. Therefore, when the MS finally
30   succeeds with decoding the expected BS identity and
transmits the measurement report to the serving BS, the
earlier made measurements may be more or less out of date,

especially in the case of a fast moving MS. This may lead to
a situation where a good BS candidate is disregarded.
Furthermore, the measured signal is the sum of all signals
transmitted from several sources reusing the same frequency,
and the total measured signal strength and/or quality may
thus be further misleading.

Another problem is that there is a limited amount
of time between the required measurement reports. Again in
GSM systems by way of example, the MS is required to send
reports for the six strongest neighbour BSs every 480 ms,
sometimes referred to as the averaging period, provided that
the identities of those six BSs have been successfully
decoded. Since the measurements must be made for one BS
after the other, there is a trade-off between a long
neighbour list and a short one. A long list includes many
potential BS selection candidates, each of which can be
briefly measured. On the other hand, a shorter list may miss
some important candidates, but those included may be
measured for a longer time, i.e., more accurately.

Furthermore, the impact of inaccurate measurement
reports may extend to affect the accuracy of network
configurations, since neighbour BS measurements are often
used to calculate cell relations forming a basis for network
planning.

To conclude, it is of great importance to obtain
reliable neighbour BS measurements with high accuracy, and
to minimise the delay time between measurements and
corresponding reports in order to improve BS selection
procedures and network planning. It is also desirable to
reduce the impact of interference on the measurements,
thereby allowing for tighter frequency reuse.

SUMMARY OF THE INVENTION

The object of this invention is to reduce or eliminate the problems outlined above. This object and others are obtained by providing a method and apparatus for performing link quality estimation of a TDMA-based wireless communication link between a mobile station and a target base station. The mobile station receives a signal on a channel frequency of the target base station, and a link quality of the received signal is measured by the mobile station. The target base station is simultaneously identified based on the same received signal, wherein the measurement is qualified if the mobile station has succeeded to identify the target base station. Otherwise, the measurement is discarded if the mobile station has failed to identify the target base station.

The measuring and identifying are thus performed simultaneously based on the same received signal. The mobile station may or may not be connected to a serving base station. If so, the measured target base station is a neighbouring base station, wherein the mobile station later reports the measurement to the serving base station, if the measurement is qualified by the expected neighbouring base station being identified properly. Link quality measurements can then be tied to specific base stations more reliably, and are at the same time up to date when reported. Further, the mobile station may be directed by the serving base station in a measurement order to select a measuring and identifying scheme which is pre-programmed in the mobile station.

The received signal is preferably measured with respect to at least one of: received signal strength (RSS),

carrier-to-interference power ratio (C/I), carrier power, and bit error rate (BER).

According to specific aspects of the invention, the received signal may include an identity of the base station which is detected by the mobile station. The received signal may further include a synchronisation channel burst from the base station including the identity.

The received signal may further include a burst from the base station including a training sequence which is estimated by the mobile station. The training sequence is then related to an identity of the base station in a way that is known by the mobile station. The identity can thus be derived from the estimated training sequence based on the known relation. A code of the training sequence may further be identical to the identity of the target base station. The burst from the target base station may be a dummy burst including the training sequence being related to the identity of the target base station.

Identifying the target base station may include attempting to detect the received signal using at least two different modulation forms. The received signal may include a dummy burst including an identity of the target base station.

Channel estimation may be conducted on the received signal with respect to the target base station for performing at least one of the measuring and identifying steps. If one or more channel estimates are derived from the received signal, the channel estimates can be determined for a set of pre-determined training sequences, a selection metric can be calculated, and the training sequence that yields the greatest selection metric can be selected.

If the target base station is unsynchronised with
the mobile station, a burst of a synchronisation channel may
be received by the mobile station for obtaining timing
information. The target base station can then be identified
5   based on the obtained timing information.

The received signal preferably includes a complete
burst period.

If the received signal includes contributions from
a plurality of unsynchronised target base stations
10   transmitting on the same frequency channel, measuring and
identifying may be performed with respect to one target base
station at a time sequentially for at least two of the
target base stations. On the other hand, if the received
signal includes contributions from a plurality of
15   synchronised target base stations transmitting on the same
frequency channel, measuring and identifying may be
performed with respect to the target base stations for at
least two of the synchronised target base stations jointly
in one operation.

20   The qualified measurement may be used for
performing base station selection for serving the mobile
station in idle or busy mode. The qualified measurement may
also be used for estimating cell relations in order to
perform network planning, or for determining the position of
25   the mobile station.

The inventive procedure may be implemented in a
mobile station having means for performing the procedure.
The inventive procedure may further be executed by means of
a computer program product comprising a software code being
30   adapted for the method to be performed in a mobile station.
The computer program product may be either directly loadable
into the internal memory of a computer in the mobile

station, or stored on a computer usable medium, including readable program for causing a computer in the mobile station to perform the method.

5   BRIEF DESCRIPTION OF THE DRAWINGS
The present invention will now be described in more detail and with reference to the accompanying drawings, in which:
- Fig. 1 is a schematic view of a communication system in which radio link quality estimation is performed
10   according to the invention.
- Fig. 2 is a schematic illustration of an exemplary TDMA burst.
- Fig. 3 is a flow chart illustrating the steps executed in a procedure according to one aspect of the invention.
15 - Fig. 4 is a flow chart illustrating the steps executed in a procedure according to another aspect of the invention.
- Fig. 5 is a schematic diagram illustrating a work flow in a mobile station according to a specific embodiment of the invention.
20

DESCRIPTION OF PREFERRED EMBODIMENTS
        Fig. 1 is a schematic view of a cellular communication network 12 including a plurality of BSs. In this example, an MS 10 is currently connected to a serving
25 BS 14. The MS 10 may be either in idle mode or in busy mode, as explained above. Initially, when the MS 10 has started the connection with the serving BS 14, the MS 10 receives from BS 14 a measurement order with a neighbour list including the broadcast frequencies and identities of a
30 plurality of predetermined neighbouring BSs, of which three are shown, 16a - 16c. If the MS 10 is in idle mode, the neighbour list is received over a control channel on a

broadcast frequency channel containing various cell
information. If the MS 10 is in busy mode, i.e., is handed
over from an old BS, not shown, to the new serving BS 14,
the neighbour list may be received over a logical control
5   channel embedded in the traffic channel used.

In both cases, the MS 10 is thereby ordered to
perform link quality measurements on the specified broadcast
frequencies during idle periods, and to send reports to the
serving BS 14 according to a predetermined schedule. The
10 schedule may be specified in the measurement order or may be
pre-programmed in the MS 10. Alternatively, the MS 10 may as
yet be unconnected to any serving BS, like for example when
the MS 10 has just been powered on. The MS then scans for
broadcast frequencies and measures the strongest frequencies
15 in order to register with a serving BS.

The link quality may be measured as at least one
of: a received signal strength (RSS), a carrier-to-
interference power ratio (C/I), a carrier power, a Bit Error
Rate (BER) or any other link quality parameter. However, the
20 invention is not limited to any particular measuring method
or schedule.

The MS 10 must also identify the BS for each
measurement in order to qualify the measurement, which means
that the MS 10 receives at least one burst during a TDMA
25 timeslot and attempts to read or estimate the received burst
in order to determine an identity of the BS. The BS
identification is typically helped by the MS 10 knowing from
the received neighbour list which target BS to expect for
each frequency.

30   According to one aspect of the invention, the
measuring and identifying activities are performed
simultaneously for each target BS based on the same received

signal. In this context, "simultaneously" means that measuring and identifying are performed more or less in parallel by different functional units in the MS, albeit not necessarily exactly at the same time. If the MS 10 thus

5   fails to identify the expected BS properly, the measurement is disregarded and a new identification attempt is made, which also involves a new simultaneous measurement. In this way, it is ensured that the measurement is really made for the identified BS, and that the measurement is up to date.

10   In GSM, a BS identity BSIC is included in bursts over the synchronisation channel SCH. In that case, the BS identification may be made by reading an SCH burst being measured.

         The BS identity is in prior systems transmitted in

15 certain logical channel bursts depending on the system defined protocol. As mentioned above for GSM, the Base Station Identity Code BSIC includes the Network Colour Code NCC and the Base station Colour Code BCC. Furthermore, the broadcast frequency channel normally comprises a plurality

20 of multiplexed logical channels including paging channels PCHs and the earlier mentioned common point-to-multipoint channels BCCH, FCCH and SCH, as well as dedicated point-to-point traffic channels TCHs. In GSM systems, the BSIC is normally included only in the SCH, and is not included in

25 the other logical channels. If the MS is in busy mode, it may therefore take some time before it receives an SCH burst for reading the BSIC.

         Moreover, all normal bursts typically include a training bit sequence, which in the GSM case is 26 bits

30 long. Exceptions from "normal" bursts may be the FCCH burst which only contains a sinus wave for frequency synchronisation, and the SCH burst which contains a longer

specific training sequence used for initial TDMA burst
synchronisation.

The training sequence in a normal burst from a
serving BS is known by the MS, and is used to facilitate
5   synchronisation and decoding or detection of the burst.
Typically, there is a set of known training sequences
comprising, e.g., eight different sequences, and the one
used in a particular burst is identified by a Training
Sequence Code TSC of, e.g., 3 bits. For the common channels
10   in GSM, the TSC is identical to the BCC, and for the other
channels, the TSC is communicated in channel assignment
messages.

According to another aspect of the invention, the
BS identity is related to the training sequence code in a
15   way that is known by mobile stations. An MS receiving a
normal burst may then determine the BS identity, regardless
of which logical channel the received burst belongs to, by
estimating the training sequence and deriving the training
sequence code therefrom. In the simplest case, the BS
20   identity is set to be identical with the training sequence
code. However, other relationships are possible.

Fig. 2 illustrates schematically an exemplary
normal burst 20 transmitted in a timeslot of a broadcast
frequency channel from a target BS included in the neighbour
25   list received by the MS. The normal burst 20 may belong to
any logical channel and includes a bit field 22 with a
training sequence, in this case arranged approximately in
the middle of the burst. The burst 20 may further include
various fields 24, 26 such as data bit fields, tail bit
30   fields etc.

According to an embodiment of the invention and
with reference to the flow chart in Fig. 3, the MS receives

a radio signal in a first step 300, including a burst, or at
least a part thereof, from a target BS. The MS measures the
link quality of the burst 20 in step 302 and simultaneously
attempts to estimate the training bit sequence in the bit
field 22 in step 304, based on the same received burst. If
it is determined in step 306 that the estimation attempt was
successful, the MS is able to determine the BS identity in
step 308 by deriving the training sequence code therefrom,
as explained above. The measurement made in step 302 is then
valid and can be used. However, if the estimation attempt
was unsuccessful, the measurement is discarded in step 310.

In this way, there will be opportunities for the
MS to determine the BS identity from all normal bursts. It
should be added here that more than one measured signal may
be needed to obtain a measurement average value.
Furthermore, the training sequence estimation may involve
known methods for detecting signals in noise and
interference, such as maximum-likelihood detection
algorithms or minimum mean-squared error methods.

Alternatively, the training sequence may be
estimated by using channel estimation according to one
aspect of the invention, which will be described below.
Channel estimation is then conducted for several candidate
training sequences, wherein the training sequence that
maximises a certain selection metric is selected. An
exemplary selection metric is the signal power estimate.

In some systems, e.g., using EDGE (Enhanced Data
rates for GSM/TDMA136 Evolution) technology, more than one
modulation form may be used for BS transmissions, and hence
further sets of training sequences. In EDGE for example,
both 8PSK modulation and GMSK modulation may be used. In
this case, the additional training sequences need also be

considered during BS identification. For blind detection of
modulation, an estimation attempt is required for each
possible modulation form.

5   The flow chart in Fig. 4 illustrates an exemplary
procedure for determining the link quality for a target BS
included in a neighbour list according to another aspect of
the invention. In this example, two different modulation
forms 1 and 2 may be used by the target BS. In a first step
400, a signal or burst is received by an MS on a channel
10   frequency to be measured according to the list. In step 402,
the link quality of the received signal is measured with
respect to a predetermined parameter, such as RSS.

In parallel with the measuring step 402, attempts
are made to estimate the training sequence (TS) using
15   modulation 1 in step 404 and using modulation 2 in step 406.
In step 408, the most probable estimation from modulation 1
or 2 is selected depending on the result. In step 410, it is
determined whether the selected estimation attempt was
successful, and if so, the BS identity can be determined in
20   step 412, thereby qualifying the measurement from step 402.
On the other hand, if the selected estimation attempt was
unsuccessful, the measurement made in step 402 is discarded
in step 416.

In cellular networks, it is a general practice to
25   transmit dummy bursts on broadcast frequency channels in
timeslots not occupied by any logical channel in order to
maintain continuous transmission. A dummy burst carries no
intelligible information and typically, a predetermined bit
pattern is transmitted. It is thus not possible to determine
30   any BS identity from such dummy bursts, which may occur
quite frequently. According to a further aspect of the
invention, dummy bursts transmitted over broadcast frequency

channels include a BS identity or a training sequence which
is related to the BS identity. This will further increase
the possibilities for mobile stations to determine the BS
identity.

5   According to further aspects of the invention, a
channel estimation procedure is used, as explained below,
for determining the BS identity from a received signal.

          Channel estimation is a well-known method used for
estimating a physical channel from received radio signals
10   during an ongoing connection with a serving BS. Channel
estimation is conducted at a receiver in the MS for a given
TSC based on the corresponding training sequence. Typically,
the purpose of channel estimation is to determine a channel
impulse response for facilitating the decoding of control
15   data and user data included in the signal. Other purposes
for using channel estimation may be to enhance link quality
measurements and training sequence estimations, which can
hence be used for BS indentification, according to the
present invention.

20   A received total signal is the sum of
contributions from plural BSs reusing the same frequency.
The signal contribution from each BS may be a superposition
of various propagation reflections of the signal transmitted
by the BS, arriving with different delays at the MS. The
25   receiver experiences effectively the signal sent over a
physical channel with various channel taps. This channel and
its taps may thus be estimated in the receiver by means of
channel estimation. As mentioned above, this can be used for
estimating a training sequence. When determining which
30   training sequence has most likely been inserted into the
transmitted signal, the training sequences, or the
equivalent TSCs, may be mapped to BS identities for

determining the BS identity according to the present
invention.

Furthermore, an estimate of the received signal
power can be calculated as the sum of the squared absolute
5   channel taps. Interference and/or noise power may also be
estimated therefrom, and the carrier-to-interference power
ratio C/I can be estimated from the signal power and the
interference and/or noise power. There are numerous known
techniques for channel estimation available, e.g., the so-
10   called least-squares estimation, which will not be described
further since the present invention is not concerned with
any particular channel estimation method or equipment.

In prior known mobile systems, channel estimation
is only conducted by MSs for signals of the connection with
15   a serving BS. According to one embodiment of the invention,
channel estimation is performed on a received signal of a
frequency channel for identifying one or more BSs, e.g.,
according to the neighbour list. Channel estimation can
further be used for measuring the link quality, either
20   together with the training sequence estimation or in a
separate calculation step.

An exemplary embodiment of training sequence
estimation comprises determining the channel estimates for a
set of pre-determined training sequences, calculating a
25   selection metric, and selecting the training sequence that
yields the maximum selection metric. The maximum selection
metric indicates that the corresponding training sequence
was the one most likely transmitted. The set of pre-
determined training sequences may be chosen in accordance
30   with the respective TSCs that are mapped to the BS
identities in the neighbour list. An exemplary selection
metric is the signal power or the C/I estimate derived from

the obtained channel estimate as explained above. For
instance, the training sequence leading to the maximum
signal power or the maximum C/I estimate may be selected. By
mapping the selected training sequence to a BS in the
neighbour list, the simultaneously made measurement is thus
ascribed to that BS for inclusion in the measurement report.

The link quality measurement may also be obtained
by conducting channel estimation for signals from a BS in
the neighbour list. Such measurements may be signal power
and C/I estimates, which may also be used as selection
metric. The benefit of such measurements is that channel
estimation inherently separates the wanted signal of the
target BS from unwanted signals of other BSs and noise. The
accuracy of the measurements is thereby enhanced compared to
previous methods based on RSS.

According to one aspect of the invention, the
received signal includes a complete burst period, thus
enabling the MS to read any information embedded therein.

A mobile network may include BSs that are either
mutually synchronised or unsynchronised with respect to
downlink TDMA burst transmissions. In the case of a mobile
network having unsynchronised BSs, an MS needs to scan
complete burst periods for detecting training sequences
properly, since the time of start and end, respectively, of
a burst from a neighbouring BS is not known by the MS.
However, this may sometimes be unsuccessful, given the
limited time available for receiving other signals than
those of a serving BS when the MS is in busy mode.
Therefore, the MS may receive only a part of a burst from
the neighbouring BS, which may not contain the entire
training sequence, depending on an estimation window size.

Moreover, the performance of training sequence estimation decreases with increasing estimation window.

According to a further aspect of the invention, the MS may determine the time of the burst period from the target BS by first searching for a burst synchronisation channel, SCH in the GSM example, on the broadcast frequency. A burst synchronisation channel can be detected and decoded reliably since it typically includes a longer training sequence than for normal bursts. From this logical channel, the MS can obtain timing information of burst periods from this particular BS. This timing information, e.g., in the form of an estimated time offset in relation to the serving BS, may then be used for measuring and decoding of normal bursts, and may also be stored in the MS for later measurements on this frequency channel.

In the case that bursts from a plurality of unsynchronised BSs reusing the same frequency channel are included in the received signal, the simultaneous measuring and BS identification can be performed by the MS from the different received signal parts coming from the target BSs, constituting the sum of signals simultaneously received from those target BSs on the same frequency. The received total signal can then be evaluated sequentially with respect to each of the target BSs, one at a time, preferably using channel estimation, by detecting the respective training sequences.

On the other hand, if the target BS is burst synchronised with the serving BS and the MS, it will be much easier for the MS to read a normal burst therefrom and estimate the training sequence properly, since the MS will automatically know where it occurs within the burst in relation to its own synchronisation with the serving BS. In

a network with synchronised BSs, the bursts and the training sequences therein will thus arrive to the MS approximately at the same time from plural surrounding BSs, at least within relatively small distances.

5   In the case that bursts from a plurality of synchronised BSs reusing the same frequency channel are included in the received signal, the simultaneous measuring and BS identification can be performed by the MS from a part of the received signal that is the sum of signals

10   simultaneously received from those target BSs on the same frequency. The received total signal can then be evaluated sequentially with respect to each of the target BSs, one at a time, preferably using channel estimation, by detecting the respective training sequences.

15   Alternatively, it is also possible to perform the evaluation with respect to each BS jointly for plural BSs, reusing the same frequency, on the same received total signal using channel estimation. In this case, the presence of overlaid synchronised training sequences of the BSs is

20   utilised in a joint training sequence estimation procedure that estimates a set of transmitted training sequences, e.g., according to a maximum-likelihood or minimum mean-squared error criterion. A joint channel estimation that estimates the radio channels simultaneously with respect to

25   all target BS signals may thus be used for this purpose. This will of course involve increased complexity, but since plural BSs are measured and identified simultaneously, the processing speed may be increased, and the measurement accuracy may be improved considerably.

30   This is illustrated in Fig. 5 as a schematic work flow in an MS 500 receiving a total signal 502. The signal 502 is the sum of synchronised bursts a - c from three BSs

transmitting on the same frequency. In this simplified
example, further signal contributions from other BSs are not
considered. The total signal 502 enters a channel estimation
unit, represented by block 504. The channel estimation
5   produces three channel estimates 506 corresponding to the
three signal contributions from bursts a - c, respectively,
by estimating the channels either sequentially or jointly.
The three channel estimates 506 are then evaluated, i.e.,
measured and identified, in parallel, represented by blocks
10   508. It will be understood that the measuring and
identifying procedure may also involve the received total
signal 502 and further calculations in the channel
estimation unit 504. If the respective BS identification was
successful, the corresponding results are entered into a
15   measurement report 510 which is finally transmitted to a
serving BS 512. Alternatively, the results can be used by
the MS to select a suitable BS to register with in the case
of the MS having no serving BS.

     The various embodiments described above have the
20   purpose of increasing the accuracy and relevance of MS
measurements on target BSs. The measurements can be tied to
specific BSs more reliably, and are at the same time more up
to date when reported and/or evaluated than in prior
solutions. Furthermore, the inventive link quality
25   estimation is more insensitive to interference, which allows
for a tighter reuse of frequencies, in particular broadcast
frequencies, in different cells of a mobile network. The
tighter frequency reuse thereby enhances the overall traffic
capacity in the network.

30   In a measurement order, the MS may be directed by
a serving BS to select any of the various measuring and

identifying schemes described above, all or some of which may be pre-programmed in the MS.

It has been assumed in the description above that the reported measurement results are primarily used for

5   selecting the most suitable BS for connection with the MS, either just powered on, or in busy or idle mode. However, the measurement results can also be used for estimation of cell relations in order to support network planning. Cell relations include, e.g., an estimated level of interference

10   if the cells are allocated the same or adjacent frequency channels for transmissions. Typical network planning tasks that may be performed based on estimated cell relations include: setting cell patterns and transmission power levels, making antenna adjustments and setting frequency

15   allocation parameters and handover thresholds.

The invention may be implemented in a computer program loadable into the internal memory of a computer in the mobile station (10), or in a computer program product stored on a computer usable medium for controlling the

20   mobile station (10).

While the invention has been described with reference to specific exemplary embodiments, the description is only intended to illustrate the inventive concept and should not be taken as limiting the scope of the invention.

25   Various alternatives, modifications and equivalents may be used without departing from the spirit of the invention, which is defined by the appended claims.

CLAIMS

1. A method of performing link quality estimation of a TDMA-
   based wireless communication link between a mobile
5   station (10) and a target base station (16a-c), wherein
   the mobile station (10) receives a signal on a channel
   frequency of the target base station (16a-c),
   characterised by the following steps:
   - measuring by the mobile station (10) a link quality of
10   the received signal,
   - simultaneously identifying the target base station (16a-
     c) based on the same received signal, and
   - qualifying the measurement if the mobile station (10) has
     succeeded to identify the target base station (16a-c), or
15   - discarding the measurement if the mobile station (10) has
     failed to identify the target base station (16a-c).

2. A method according to claim 1, wherein the mobile station
   (10) is connected to a serving base station (14) and the
20   target base station (16a-c) is a neighbouring base
   station, **characterised by** the further step of reporting
   the qualified measurement by the mobile station (10) to
   the serving base station (14).

25 3. A method according to claim 2, **characterised in** that the
   mobile station (10) is directed by the serving base
   station (14) in a measurement order to select a measuring
   and identifying scheme for performing the steps of
   measuring and identifying, wherein the scheme is pre-
30   programmed in the mobile station (10).

4. A method according to any of claims 1 - 3, **characterised in** that the received signal is measured with respect to at least one of: received signal strength (RSS), carrier-to-interference power ratio (C/I), carrier power, and bit error rate (BER).

5. A method according to any of claims 1 - 4, **characterised in** that the received signal includes an identity of the target base station (16a-c) which is detected by the mobile station (10).

6. A method according to claim 5, **characterised in** that the received signal includes a synchronisation channel burst from the target base station (16a-c) including the identity.

7. A method according to any of claims 1 - 4, wherein the received signal includes a burst from the target base station (16a-c) including a training sequence, **characterised in** that the identifying step includes the substeps of:
- estimating the training sequence by the mobile station (10), wherein the training sequence is related to an identity of the target base station (16a-c) in a way that is known by the mobile station (10), and
- deriving the target base station identity from the estimated training sequence based on the known relation.

8. A method according to claim 7, **characterised in** that a code of the training sequence is identical to the identity of the target base station (16a-c).

9. A method according to any of claims 1 - 8, **characterised
   in** that the identifying step includes attempting to
   detect the received signal using at least two different
   modulation forms.

10. A method according to any of claims 1 - 9, **characterised
    in** that the received signal includes a dummy burst
    including an identity of the target base station (16a-c).

11. A method according to claim 7 or 8, **characterised in** that
    the burst from the target base station (16a-c) is a dummy
    burst including the training sequence being related to
    the identity of the target base station (16a-c).

12. A method according to any of claims 1 - 4 and 7 - 11,
    characterised in that channel estimation is conducted on
    the received signal with respect to the target base
    station (16a-c) for performing at least one of the
    measuring and identifying steps.

13. A method according to claim 12, wherein one or more
    channel estimates are derived from the received signal,
    characterised in that identifying step includes the
    substeps of:
    - determining the channel estimates for a set of pre-
      determined training sequences,
    - calculating a selection metric, and
    - selecting the training sequence that yields the greatest
      selection metric.

14. A method according to any of claims 1 - 13, wherein the
    target base station (16a-c) is unsynchronised with the

mobile station (10), **characterised in** that the mobile station (10) receives a burst of a synchronisation channel for obtaining timing information, wherein the identifying step is based on the obtained timing information.

15. A method according to any of claims 1 - 14, **characterised in** that the received signal includes a complete burst period.

16. A method according to claim 12, wherein the received signal includes contributions from a plurality of unsynchronised target base stations transmitting on the same frequency channel, **characterised in** that the steps of measuring and identifying are performed with respect to one target base station at a time sequentially for at least two of the target base stations.

17. A method according to claim 12, wherein the received signal includes contributions from a plurality of synchronised target base stations transmitting on the same frequency channel, **characterised in** that the steps of measuring and identifying are performed with respect to the target base stations for at least two of the synchronised target base stations jointly in one operation.

18. A method according to any of claims 1 - 17, **characterised in** that the qualified measurement is used for at least one of: performing base station selection for serving the mobile station (10) in idle or busy mode, estimating cell

relations and determining the position of the mobile
station (10).

19. A mobile station (10) including means for receiving a
    signal on a channel frequency of a target base station
    (16a-c) for performing link quality estimation of a TDMA-
    based wireless communication link with the target base
    station (16a-c), **characterised in** that the mobile station
    (10) further includes:

- means for measuring a link quality of the received
  signal,
- means for identifying the target base station (16a-c)
  simultaneously based on the same received signal, and
- means for qualifying the measurement if the mobile
  station (10) has succeeded to identify the target base
  station (16a-c) or discarding the measurement if the
  mobile station (10) has failed to identify the target
  base station (16a-c).

20. A mobile station (10) according to claim 19, wherein the
    mobile station (10) is connected to a serving base
    station (14) and the target base station (16a-c) is a
    neighbouring base station, **characterised in** that the
    mobile station (10) further includes means for reporting
    the qualified measurement by the mobile station (10) to
    the serving base station (14).

21. A mobile station (10) according to claim 20,
    characterised in that the mobile station (10) further
    includes at least one pre-programmed measuring and
    identifying scheme, wherein the mobile station (10) is
    directed by the serving base station (14) in a

measurement order to select a measuring and identifying
scheme.

22. A mobile station (10) according to any of claims 19 - 21,
    characterised in that the measuring means measures the
    received signal with respect to at least one of: received
    signal strength (RSS), carrier-to-interference power
    ratio (C/I), carrier power and bit error rate (BER).

23. A mobile station (10) according to any of claims 19 - 22,
    characterised in that the identifying means detects an
    identity of the target base station (16a-c) included in
    the received signal.

24. A mobile station (10) according to any of claims 19 - 22,
    characterised in that the identifying means estimates a
    training sequence included in the received signal,
    wherein the training sequence is related to an identity
    of the target base station (16a-c) in a way that is known
    by the mobile station (10), and that the identifying
    means further derives the identity from the estimated
    training sequence based on the known relation.

25. A mobile station (10) according to any of claims 19 - 24,
    characterised in that the identifying means attempts to
    detect the received signal using at least two different
    modulation forms.

26. A mobile station (10) according to any of claims 19 - 22,
    24 and 25, characterised in that the mobile station (10)
    further includes means for conducting channel estimation
    on the received signal with respect to the target base

station (16a-c), which is used for measuring and
identifying.

27. A mobile station (10) according to claim 26, wherein one
or more channel estimates are derived from the received
signal, **characterised in** that the mobile station (10)
further includes:
- means for determining the channel estimates for a set of
  pre-determined training sequences,
- means for calculating a selection metric, and
- means for selecting the training sequence that yields the
  greatest selection metric.

28. A mobile station (10) according to any of claims 19 - 27,
wherein the target base station (16a-c) is unsynchronised
with the mobile station (10), **characterised in** that the
mobile station (10) further includes means for receiving
a burst of a synchronisation channel for obtaining timing
information, wherein the identifying means uses the
obtained timing information.

29. A mobile station (10) according to claim 26, wherein the
received signal includes contributions from a plurality
of unsynchronised target base stations transmitting on
the same frequency channel, **characterised in** that the
measuring and identifying means measures and identifies
with respect to one target base station at a time
sequentially for at least two of the target base
stations.

30. A mobile station (10) according to claim 26, wherein the
received signal includes contributions from a plurality

of synchronised target base stations transmitting on the
same frequency channel, **characterised in** that the
measuring and identifying means measures and identifies
jointly with respect to the target base stations for at
least two of the synchronised target base stations in one
operation.

31. A mobile station (10) according to any of claims 19 - 30,
characterised in that the mobile station (10) further
includes means for performing base station selection
based on the measurement results.

32. A computer program product directly loadable into the
internal memory of a computer in the mobile station (10),
including software code means for performing the method
according to any of claims 1-18.

33. A computer program product stored on a computer usable
medium, including readable program for causing a computer
in the mobile station (10) to perform the method
according to any of claims 1-18.

AMENDED CLAIMS
[received by the International Bureau on 28 October 2002 (28.10.02);
original claims 1 and 19 amended;
remaining claims unchanged (3 pages)]

1. A method of performing link quality estimation of a TDMA-
    based wireless communication link between a mobile station
    (10) and a target base station (16a-c), wherein the mobile
    station (10) receives a signal on a channel frequency of the
    target base station (16a-c), **characterised by** the following
    steps, executed in the mobile station:

-   measuring a link quality of the received signal, and
    simultaneously identifying the target base station (16a-c) in
    parallel with the measurement based on the same received
    signal, and

-   qualifying the measurement as valid if the mobile station (10)
    has succeeded to identify the target base station (16a-c)
    based on the received and measured signal, or

-   discarding the measurement if the mobile station (10) has
    failed to identify the target base station (16a-c) based on
    the received and measured signal.

2. A method according to claim 1, wherein the mobile station
    (10) is connected to a serving base station (14) and the
    target base station (16a-c) is a neighbouring base station,
    characterised by the further step of reporting the qualified
    measurement by the mobile station (10) to the serving base
    station (14).

3. A method according to claim 2, **characterised in** that the
    mobile station (10) is directed by the serving base station
    (14) in a measurement order to select a measuring and
    identifying scheme for performing the steps of measuring and
    identifying, wherein the scheme is pre-programmed in the
    mobile station (10).

4. A method according to any of claims 1 - 3, **characterised in**
    that the received signal is measured with respect to at least

AMENDED SHEET (ARTICLE 19)

16. A method according to claim 12, wherein the received signal
includes contributions from a plurality of unsynchronised
target base stations transmitting on the same frequency
channel, **characterised in** that the steps of measuring and
identifying are performed with respect to one target base
station at a time sequentially for at least two of the target
base stations.

17. A method according to claim 12, wherein the received signal
includes contributions from a plurality of synchronised
target base stations transmitting on the same frequency
channel, **characterised in** that the steps of measuring and
identifying are performed with respect to the target base
stations for at least two of the synchronised target base
stations jointly in one operation.

18. A method according to any of claims 1 - 17, **characterised in**
that the qualified measurement is used for at least one of:
performing base station selection for serving the mobile
station (10) in idle or busy mode, estimating cell relations
and determining the position of the mobile station (10).

19. A mobile station (10) including means for receiving a signal
on a channel frequency of a target base station (16a-c) for
performing link quality estimation of a TDMA-based wireless
communication link with the target base station (16a-c),
characterised in that the mobile station (10) further
includes:
- means for measuring a link quality of the received signal and
for simultaneously identifying the target base station (16a-
c) in parallel with the measurement based on the same
received signal,
- means for qualifying the measurement as valid if the mobile
station (10) has succeeded to identify the target base

station (16a-c) based on the received and measured signal, and

- means for discarding the measurement if the mobile station (10) has failed to identify the target base station (16a-c) based on the received and measured signal.

20. A mobile station (10) according to claim 19, wherein the mobile station (10) is connected to a serving base station (14) and the target base station (16a-c) is a neighbouring base station, **characterised in** that the mobile station (10) further includes means for reporting the qualified measurement by the mobile station (10) to the serving base station (14).

21. A mobile station (10) according to claim 20, **characterised in** that the mobile station (10) further includes at least one pre-programmed measuring and identifying scheme, wherein the mobile station (10) is directed by the serving base station (14) in a measurement order to select a measuring and identifying scheme.

22. A mobile station (10) according to any of claims 19 - 21, **characterised in** that the measuring means measures the received signal with respect to at least one of: received signal strength (RSS), carrier-to-interference power ratio (C/I), carrier power and bit error rate (BER).

23. A mobile station (10) according to any of claims 19 - 22, **characterised in** that the identifying means detects an identity of the target base station (16a-c) included in the received signal.

24. A mobile station (10) according to any of claims 19 - 22, **characterised in** that the identifying means estimates a training sequence included in the received signal, wherein
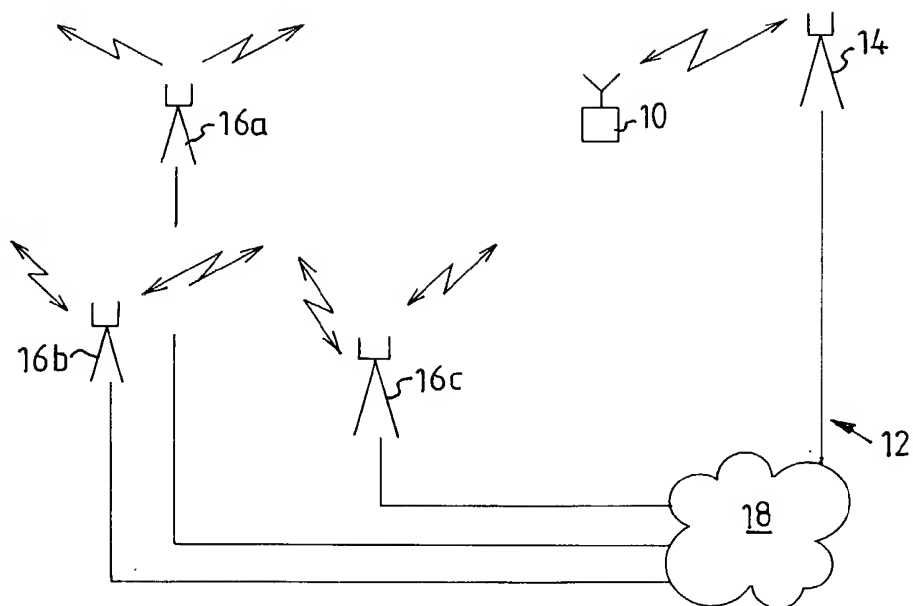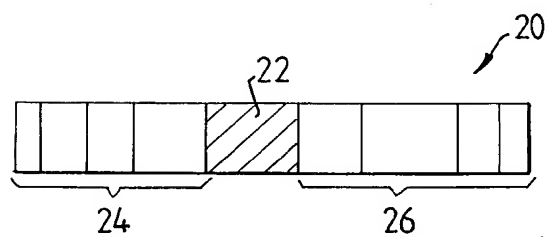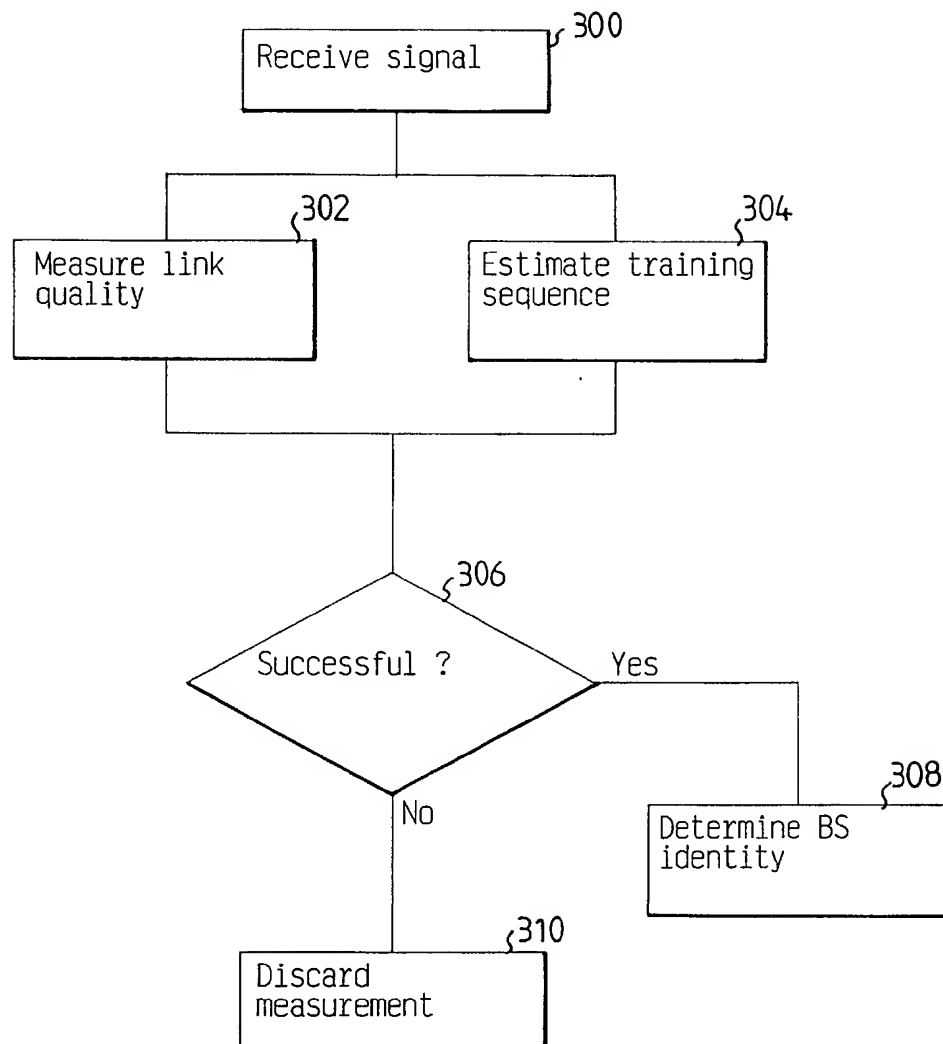
1 / 4

FIG. 1

FIG. 2

2/4

FIG. 3

3 / 4
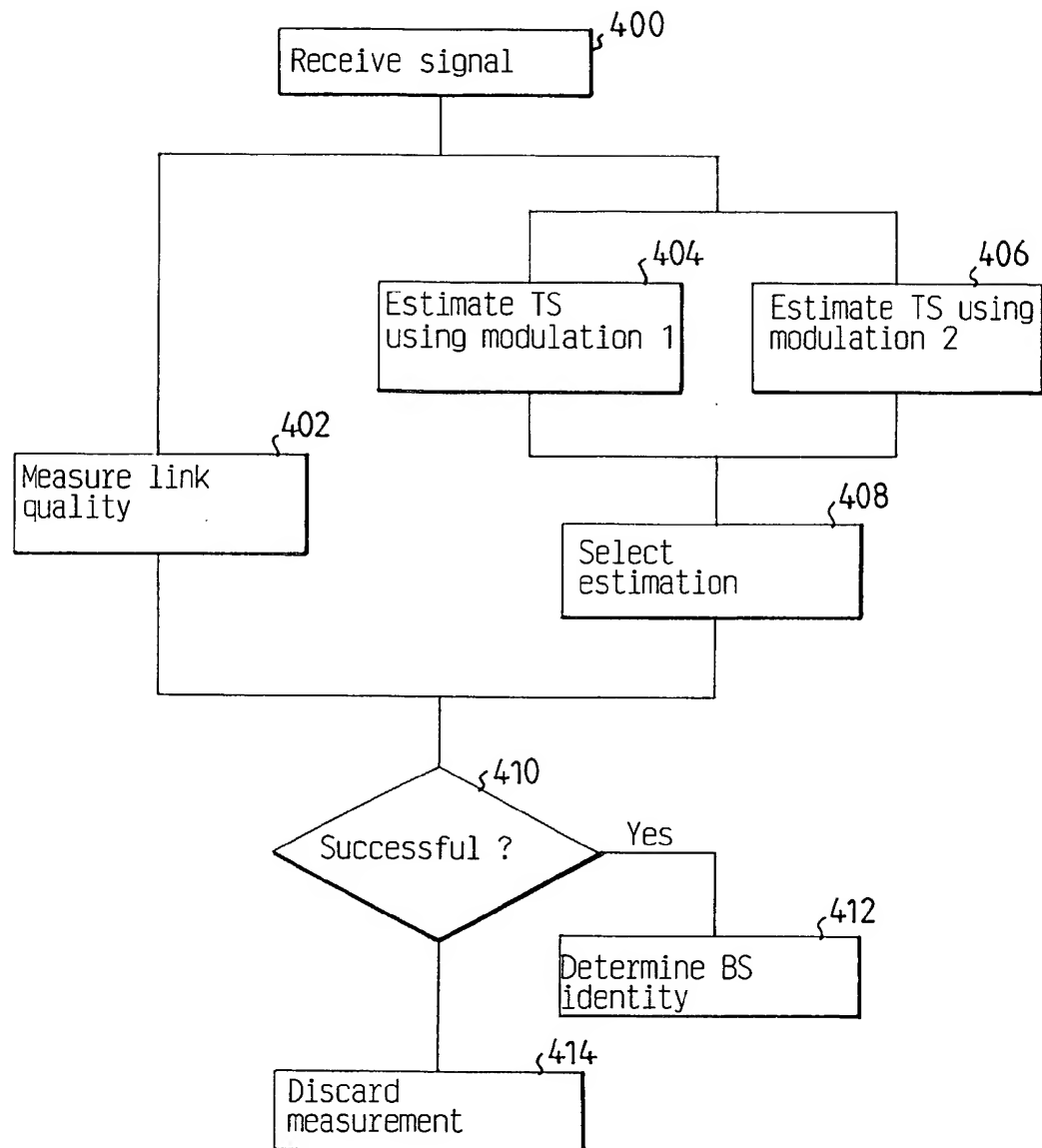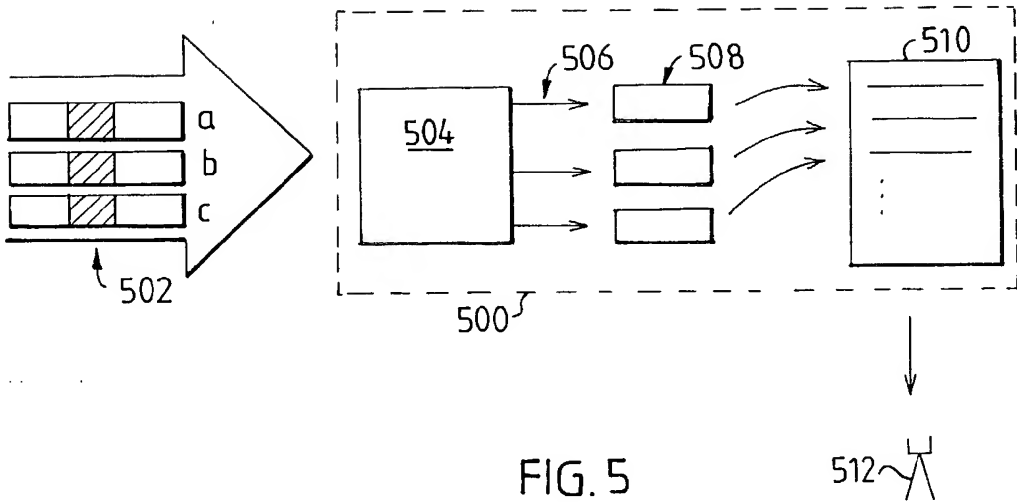
```
┌─────────────────┐ 400
│ Receive signal  │
└─────────────────┘
```

┌──────────────────────┐ 404   ┌──────────────────────┐ 406
│ Estimate TS   │   │ Estimate TS using   │
│ using modulation 1   │   │ modulation 2   │
└──────────────────────┘   └──────────────────────┘

┌──────────────────┐ 402   ┌──────────────────┐ 408
│ Measure link   │   │ Select   │
│ quality   │   │ estimation   │
└──────────────────┘   └──────────────────┘

◇ Successful ? 410 —— Yes —→ ┌──────────────────┐ 412
                              │ Determine BS   │
                              │ identity   │
                              └──────────────────┘

┌──────────────────┐ 414
│ Discard   │
│ measurement   │
└──────────────────┘

FIG. 4

FIG. 5

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04Q 7/38, H04Q 7/34, H04B 17/00, H04Q 7/22
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04Q, H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0886453 A3 (NOKIA MOBILE PHONES LTD.), 23 December 1998 (23.12.98), abstract, See the whole document	1-33
A	US 5966657 A (SPORRE), 12 October 1999 (12.10.99), column 9, line 39 - line 67; column 10, line 52 - line 60	2-6,32-33
A	WO 0122600 A3 (TELEFONAKTIEBOLAGET LM ERICSSON (PUBL)), 29 March 2001 (29.03.01), abstract	2

[X] Further documents are listed in the continuation of Box C.   [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 August 2002	2 9 -08- 2002

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Form PCT/ISA/210 (second sheet) (July 1998)

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 0069205 A1 (MOTOROLA LIMITED), 16 November 2000 (16.11.00), claims 1-14, abstract	6,12,15
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A	Michel Mouly; Marie-Bernadette Paulet "The GSM system for Mobile Communications" 1992 Cell & Sys ISBN 2-9507190-0-7 page 233, 256, 257	7,8,12,13, 24,26,27
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				JP	2002505824	T	19/02/02
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				CN	1271500	T	25/10/00
				DE	19882540	T	21/09/00
				GB	0001308	D	00/00/00
				GB	2344972	A	21/06/00
				SE	0000166	A	24/03/00
				TW	443051	B	00/00/00
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				GB	9910552	D	00/00/00
				US	6256494	B	03/07/01